Modeling Of Selected Continental Slope Processes

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LONG-TERM GOALS

My long-term goals are to improve our understanding of the physical evolution of continental slope morphology and stratigraphy, and enhance our ability to extract stratigraphic information from geophysical data.

OBJECTIVES

The objectives of this project are to:
(1) Characterize the effect of spatial variations in deposition and erosion on the fluid flow, pore pressures and thus the stability of continental slope sediments.
(2) Constrain the impact of individual turbidity currents on seafloor evolution.
(3) Develop a technique for correlating stratigraphy complicated by spatial variations in sedimentation, erosion and post-depositional processes.
(4) Assess the fidelity to which various seismic sources image stratigraphy.

APPROACH

I am exploring the linkages between sedimentation/erosion, fluid flow, pore-pressure evolution and slope stability with M. Tice (Stanford) using numerical modeling. I am also using numerical modeling in collaboration with J. Imran (U. S. Caro.), G. Parker (U. Minn.) and J. Syvitski (U. Colo.) to simulate the dynamics of turbidity currents and their role in seafloor evolution. Correlation of any two series of down-core measurements of stratigraphy (e.g., lithology, physical properties or log response) is being done with D. Martinson (L-DEO) and is being automated on the basis of variations in measurement amplitude. And I am investigating the stratigraphic content of seismic reflection data with W. Gouveia (Mobil), C. Paola (U. Minn.) and D. Herrick (Duke) by simulating seismograms of experimental stratigraphy formed in a new laboratory basin at St. Anthony Falls Laboratory (Univ. Minn.).

WORK COMPLETED

(1) A 2D finite-element model has been developed that solves for the evolution of both stresses and hydraulic head in a slope composed of saturated sediments (Figure 1). The model builds on the 2D analytical model of slope stability by Mello and Pratson (1999).

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**

4. TITLE AND SUBTITLE **Modeling Of Selected Continental Slope Processes**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Duke University ,Division of Earth and Ocean Sciences,Durham,NC,27708-0230**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

(2) A 1D numerical model of turbidity current dynamics has been developed (Pratson et al., in press (a)) and compared to a similar model of debris flow dynamics (Pratson et al., in press (b)). These 1D models have now been extended to 2D, though the latter versions are still being refined.
(3) A model has also been developed for simulating sediment physical properties from digital photographs of experimental stratigraphy (Pratson et al., 1998a, 1998b; Pratson et al., 1999; Pratson and Gouveia, in review). This simulation is then input to algorithms that generate synthetic seismic data ranging from idealistic, vertical-incident seismograms to realistic 2D multichannel seismic data. The physical-property model is being improved (Herrick et al., in press) and now yields synthetic core data (Figure 2), which will be used to test the correlation algorithm.

RESULTS

(1) The 2D finite-element model reproduces the steady-state solution for fluid flow in a saturated slope as presented by Iverson and Reid (1992) (Figure 1). This confirms that the model works and is ready to be exercised on transient problems related to non-uniform sedimentation/erosion on seafloor slopes.
(2) The modeling comparison of debris flows versus turbidity currents demonstrates that the tendency of debris flows to conserve their mass relative to turbidity currents, which change theirs through erosion/deposition and the entrainment of ambient water, leads to fundamental differences in the distributions, shapes and stacking of their deposits.
(3) The modeling of synthetic seismograms from experimental stratigraphy illustrates the filtering effect of different seismic sources on stratigraphic resolution. It also shows that seismic artifacts such as diffractions, multiples and side echoes introduce lower frequencies into seismic data that mask important stratal geometries used to interpret the data.

IMPACT/APPLICATIONS

With further use, the 2D finite element model coupling stress and hydraulic head should improve our understanding of fluid flow within passive continental slopes and its potential role in slope destabilization. The numerical modeling of turbidity current dynamics is presenting new ideas on how an important marine process forms seafloor morphology and stratigraphy, a central goal of STRATAFORM. And the synthetic seismic modeling of experimental stratigraphy is offering a novel approach for constraining what is and isn't retained of stratigraphy in seismic reflection data.

TRANSITIONS

The 1-D turbidity current model has been incorporated into the 2D basin evolution model, SEDFLUX, which is being developed by James Syvitski (Univ. Colorado) and other STRATAFORM researchers. The model is also being tested by a number of oil companies (e.g., Mobil, Texaco, Exxon, and Shell). Additionally, several of these companies are using the synthetic seismic modeling of the experimental stratigraphy for teaching and research purposes.

RELATED PROJECTS

Over the past year, I've aided in two regional to global-scale quantitative analyses involving continental slope morphologies: (i) an analysis of the shapes of continental margins around the world

(O'Grady et al., in review), and (ii) an analysis of the shapes, sizes and distributions of seafloor failures along the US margins (McAdoo et al., in review). I am also involved in an analysis of the relation between the dynamics of internal waves and the gradients of the continental slopes within the STRATAFORM study areas (Cacchione et al., in review).

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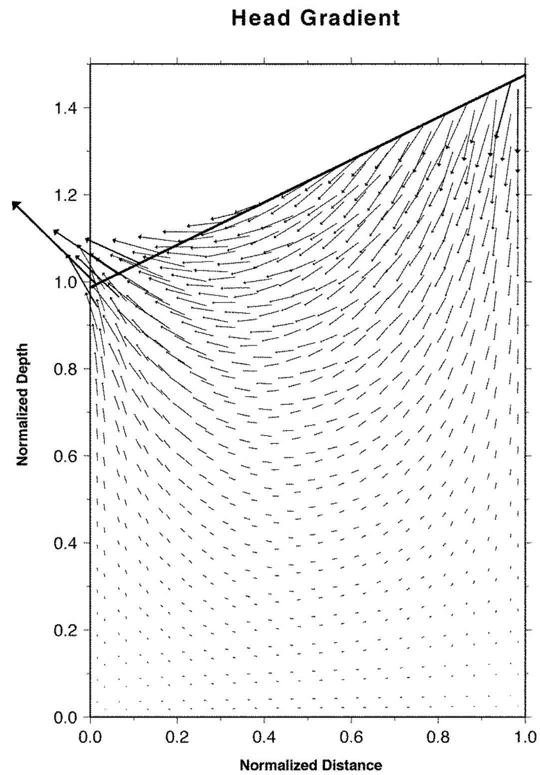

Figure 1. Steady-state head gradient within a subaerial slope of saturated sediments dipping 30°. This result agrees with the solution of Iverson and Reid (1992), verifying that the 2D model coupling the evolution of stresses and fluid flow within a sedimented slope is working.

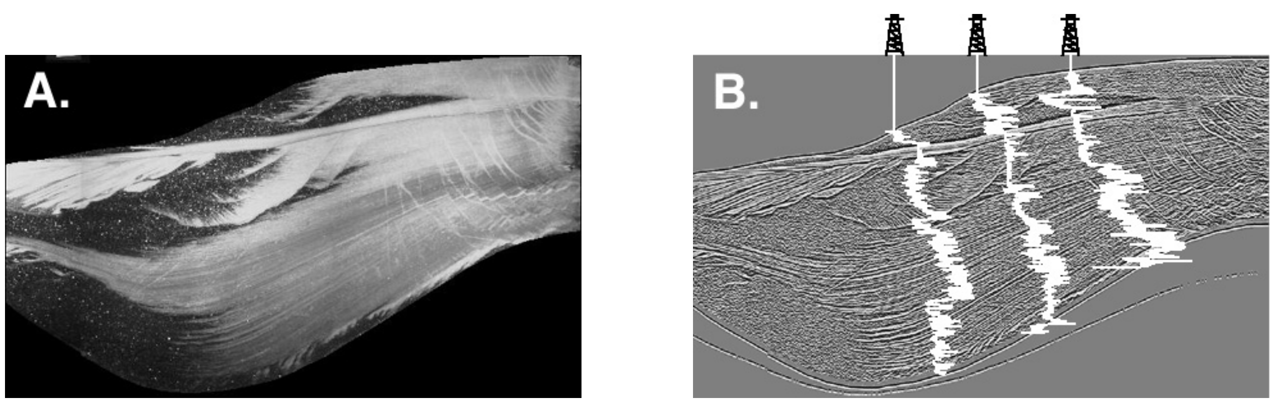

Figure 2. A. Digital photograph of experimental stratigraphy formed in the XS Basin at St. Anthony Falls Laboratory (Univ. Minn.). B. Idealistic, vertical-incident seismogram of stratigraphy (peak frequency = 400 Hz) overlain by three simulated well logs.